THE NAVY'S SHIPHANDLING RESEARCH AND DEVELOPMENT MODEL

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ABSTRACT

The U.S. Navy has undertaken a shiphandling trainer design and development project for the purpose of upgrading existing training. Naval officers at all career levels have had fewer opportunities to acquire and practice shiphandling skills because of a considerable reduction in underway steaming time. A functional design has been generated that describes several design alternatives ranging from expensive, full mission, high fidelity, bridge simulators to smaller part-task devices that train principles and concepts. The Navy has determined that a relatively small, less expensive part-task trainer may meet most of the requirements for training basic and intermediate level shiphandling skills in the areas of shiphandling: alongside, in restricted waters, in open ocean, during mooring and anchoring, and for tactical operations. A model device has been developed that allows the Navy an opportunity to evaluate each of the proposed trainer subsystems under consideration for final engineering design. Major subsystems include a computer generated imagery (CGI) visual display, computer aided instruction (CAI), and a situation display that affords immediate and delayed performance feedback during and after training exercises. Future research using this model will provide important information concerning subsystem training effectiveness and the fidelity requirements for major areas of shiphandling training.

INTRODUCTION

Conning officers, who are responsible for the safe maneuvering of ships require a specialized set of cognitive skills. Traditionally junior officers have been provided both the time and opportunity to develop these skills on-the-job while underway. Unfortunately, as the Navy's high technology operational systems have increased in complexity, the training responsibilities of commanding officers has taxed schedules and facilities to their limit. More of what a naval officer does at sea has been devoted to tactical and engineering requirements leaving a limited amount of time for training and practice of the skills of shiphandling. In addition, continuing high fuel costs and shortages have reduced total underway time, which had been used for practice and training of shiphandling skills.

To maximize training effectiveness for the time and resources that are available, the Navy has initiated a program to provide quality shiphandling training for all officers who require it. This paper briefly describes the program and then explores in some detail a research project aimed at developing one component of the shiphandling training system - a part-task device.

Training Problem

Several years ago the Naval Training Equipment Center (NAVTRAEQUIPCEN) began to closely examine the training requirements of Navy shiphandlers to determine ways for enhancing the quality and increasing the opportunities for shiphandling training (Hanley, Bertsche, and Hammell, 1982).[1] As a first step, a problem analysis was undertaken that resulted in a shiphandling job and task analysis of the Surface Warfare Officer (SWO). Supporting skills and knowledge elements were derived which were compared to those addressed in existing Navy shiphandling training programs. Current programs were compared to the training demand for officers serving in seagoing commands who were expected to handle the ship as part of their job. An estimate of the total training demand was made to understand the magnitude of training need and the qualitatively different types of training necessary to address most shiphandling training requirements.

Training demand was estimated by surveys of the major school and operational SWO commands. In addition to the total number of Surface Warfare Officer billets (approximately 12,000), several other factors were examined to help identify existing training requirements including:

Types of Training Required. The numbers of officers within basic, intermediate, and advanced skill levels were estimated. These skill groupings are consistent with career development paths described in NAVPERS 15197A ("Unrestricted Line Officer Career Guidebook"). Numbers were derived from counting the number of active Navy ships in service and estimating the number of officers who regularly conn a ship. This method provided conservative estimates of training requirements.

During 1981 it was estimated that approximately 750 basic, 1250 intermediate, and 767 advanced officers would be available for training based on a 50 percent availability of officers assigned to seagoing commands. These large numbers of trainees would require initial training and periodic refresher training.

Training Opportunities. A survey was made of Navy officers for time spent at sea under instruction and actually conning a ship. Additionally, training opportunities at shore facilities were surveyed. It was clear from the analysis that additional training sites and media must be developed to supplement existing Navy training efforts. In either area, opportunities for training were found to be extremely limited. Existing training facilities ashore were few, and equipment limited in its availability to school and operational commands. At-sea opportunities for training have been reduced because of a fleet wide reduction in steaming time.

Location. The dispersion of fleet units across major U.S. ports on either coast requires the distribution of training capabilities in many locations rather than several central ones. The Surface Warfare Officer Schools in Newport, Rhode Island, and San Diego, California; the Fleet Training Centers in Norfolk, Virginia, and San Diego, California; the Naval Academy, Reserve Centers and a number of major naval bases are all potential offerers of initial and refresher shiphandling training.

Shiphandling Training System

As a result of the training analysis, and subsequent media selection process, a shiphandling training system has been derived. The media chosen for delivering training ranged from simple audio-visual aids to a very complex, full bridge simulator which incorporates a 220-degree horizontal field of view visual scene. A number of similar shiphandling simulators are in existence today. The level of visual fidelity which they provide is necessary for the training and practice of intermediate and advanced shiphandlers. The cost to the Navy for these simulators, however, may prohibit their acquisition. In addition, there is some question as to whether basic shiphandling trainees can benefit fully from a high fidelity simulator with a limited number of instructional features.

To fill the gap which exists between audio/visual media and full bridge simulators, the NAVTRAEQUIPCEN has recommended that a relatively low-cost, part-task device be developed which will be used to teach basic shiphandlers the concepts and principles necessary to gain shiphandling cognitive skills. The part-task shiphandling device which is described in detail below, is the first of its kind to incorporate visual imagery, computer-assisted instruction and a plan position indicator in the same device. In order to determine the efficacy of this type of approach and also to examine some of the research issues which must be answered, a preprototype model of the part-task device is being developed by the Human Factors Research Laboratory of NAVTRAEQUIPCEN.

PART-TASK SHIPHANDLING TRAINING DEVICE MODEL

The model (Figure 1) called PARTT-SHIP will be used as a research tool to establish the degree of training effectiveness resulting from its current design. The goal of the PARTT-SHIP program is to demonstrate the training effectiveness of a low cost shiphandling training capability which can be distributed to training locations where need is demonstrated. As a research tool, the PARTT-SHIP design is flexible and reconfiguration is possible to examine the unique contributions of its major subsystems to the total training effect. Each subsystem is explained in the following paragraphs.

Computer Generated Imagery (CGI)

A computer generated imaging subsystem is provided that displays a 150-degree (75 degrees either side relative to ownship's forward longitudinal axis) horizontal field of view (Figure 2). The vertical field of view is 22.5 degrees, 5.6 degrees up and 16.9 degrees down. The scene is full color including ownship's bow and various day and nighttime images.

Plan Position Indicator (PPI)

A "birds eye" view CRT display of an exercise area is provided during exercises (Figure 3). Ownship is at the center of the screen. Land edges, piers, channel edge, etc., are shown in solid and dashed line format. The display is capable of supporting instruction in docking, anchoring, tug handling, and restricted waters navigation through a series of specialized display enhancements. A series of vector functions representing ownship's predicted, actual, and historic movements aid instruction in the concepts and principles of shiphandling.

Computer Aided Instruction (CAI)

Giving the student a means for individually operating the model device will allow the instructor to focus on the quality of instruction and the needs of the student. Automation of this sequence reduces instructor burdens for mechanically controlling training. A dedicated CAI plasma display introduces the student to exercise objectives; gives tutorial by way of "help" functions prior to exercise run, scores performance and displays feedback to the student. Subject areas are under the direction of the instructor and he controls every portion of the training sequence from an instructor console, should he desire.

Training scenarios have been designed to simulate the real world demands of maneuvering a single screwed Navy combatant (FFG-7) in a channel although any ship can be modelled. Variable wind and current effects are simulated in an ecologically valid manner to increase the difficulty of training scenarios according to the stage of training and skill level of a student.

PARTT-SHIP Functional Description

The PARTT-SHIP model is enclosed in a training carrel with approximate dimensions of 10 feet wide, 6 feet high, and 6 feet deep. It accommodates three students comfortably at the control panels. Students alternate as conning officer, auxiliary control panel operator, and helm operator. Auxiliary panel and helm operators are seated while the student acting as conning officer is free to move about the carrel. In addition to the trainer, the carrel contains a small chart table and a chart storage facility. Trainees not conning the ship operate the trainer under the direction of the student acting as conning officer. In its current con-

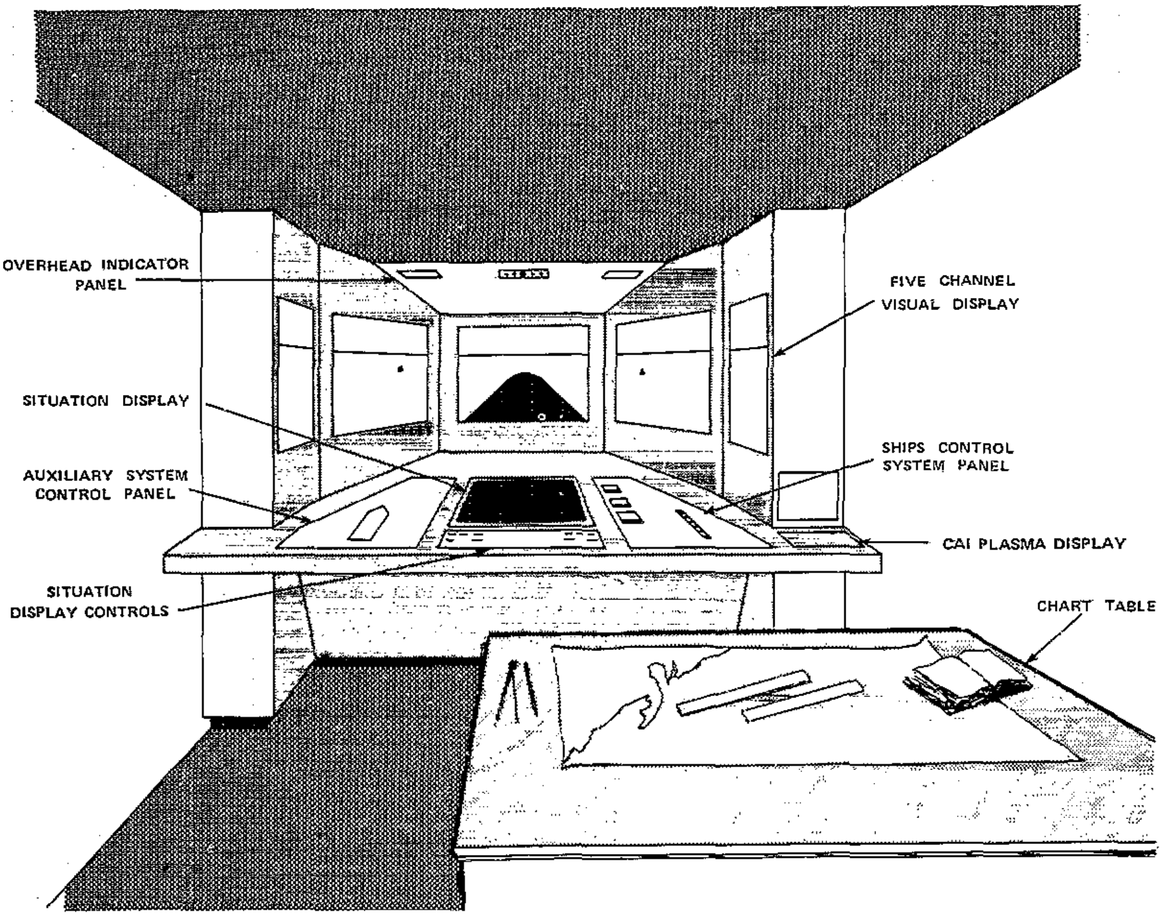

Figure 1. PARTT-SHIP Device

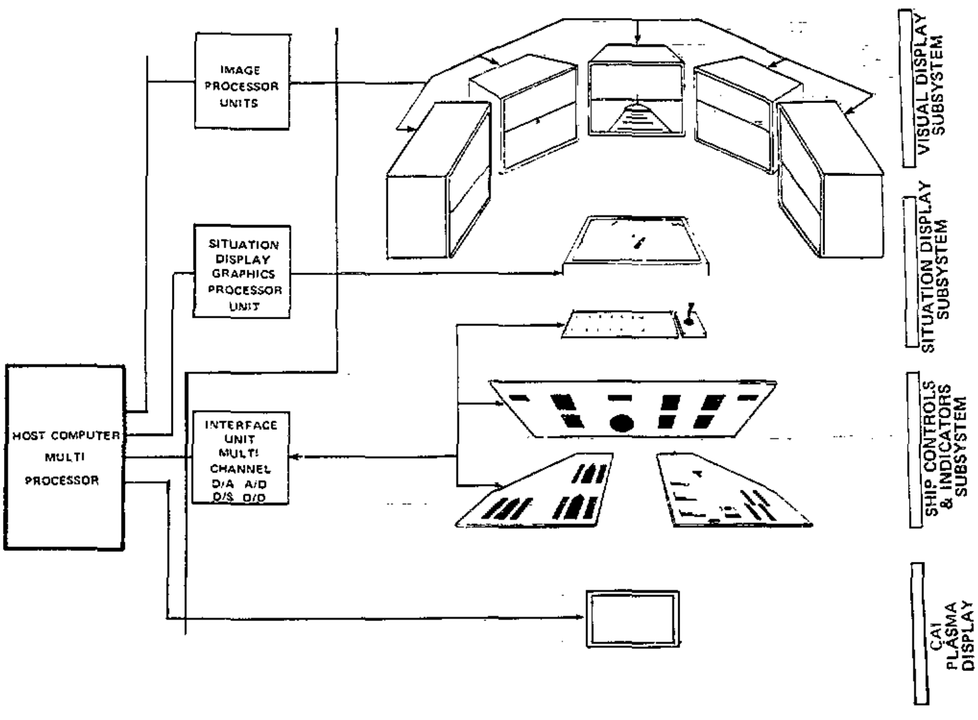

Figure 2. PARTT-SHIP Subsystems

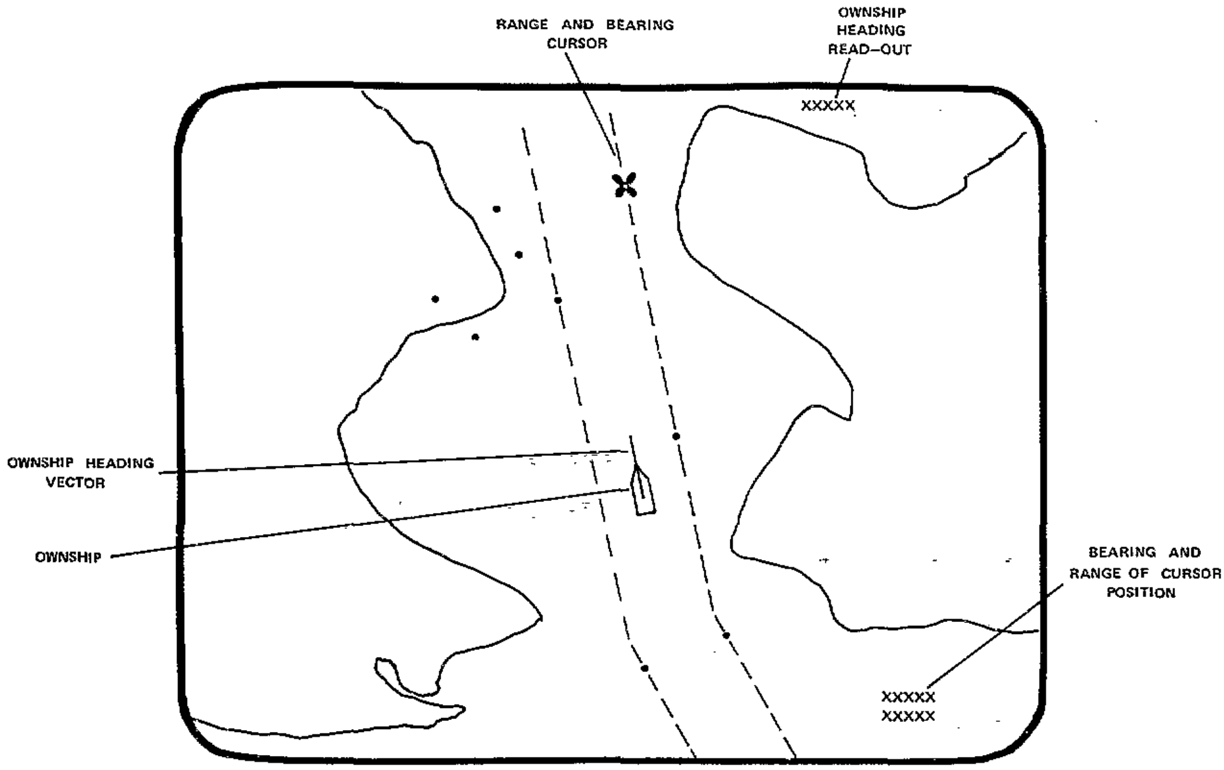

Figure 3. Typical Plan Position Indicator Display

figuration the instructor manually controls a fixed sequence of assigned instructional steps that are dependent upon the students achieving a preset criterion level of performance. Practice exercises are selected by the instructor and each simulator exercise scenario is initialized automatically. The trainee may run, freeze, or terminate the exercise scenario. Performance measures are automatically recorded by the PARTT-SHIP device and can be displayed as instructional feedback following exercise scenarios. In a production mode, it is anticipated that many of the functions currently performed by the instructor could be automated.

The device provides a real time, dynamic simulation of a selected ownship and exercise area. Generic stylized ship controls are provided which allow the trainee to control the ship's rudder, engine, propeller pitch, auxiliary propulsion units, anchors, and servicing tugboats. The status of these controls and ship performance parameters are displayed on generic indicators. The principal display for the trainee is computer generated imagery in the five-CRT configuration that comprises a 150-degree horizontal field of view. This is coordinated with an enhanced plan position indicator (PPI) representation of the geographic area that provides a "birds-eye" view of the exercise and ownship's position. The situation display also presents the future course of the ship based on external sources acting on the ownship and an estimated prediction of the ship maneuvering response to various trial rudder and engine commands. The visual system uses computer generated imagery (CGI) technology that generates images of simple aids to navigation, docking structures, and ownships bow for day conditions. Night conditions consist of lights on traffic ships, and cultural objects/land for night conditions. The training device may be operated with either or both the situation display and visual display systems.

The FFG-7 model includes auxiliary propulsion unit characteristics, autopilot, passing ship interactions, anchor effects, tug effects, wind, and current effects. Figure 2 is a simplified system diagram of the PARTT-SHIP hardware configuration that has been developed for the demonstration model. Major subsystems are:

- CAI controls and display systems
- Ship control and indicator subsystem
- Situation display subsystem
- Visual display subsystem

The model is driven by a host computer multiprocessor that controls the functions of image processing units, radar graphics processors, and a multichannel interface unit.

Situation Display. The situation display is provided to allow the student an enhanced navigation and maneuvering display in place of a traditional radar. The PARTT-SHIP model is not a radar trainer. The PPI display is a situation presentation format that was chosen over a traditional radar display because of its increased training capability through special instructional features.

The display includes distinct symbols for anchors, tugboats, piers, and other navigational aids. Channel boundaries show areas and motion vectors that can be displayed on the PPI to aid

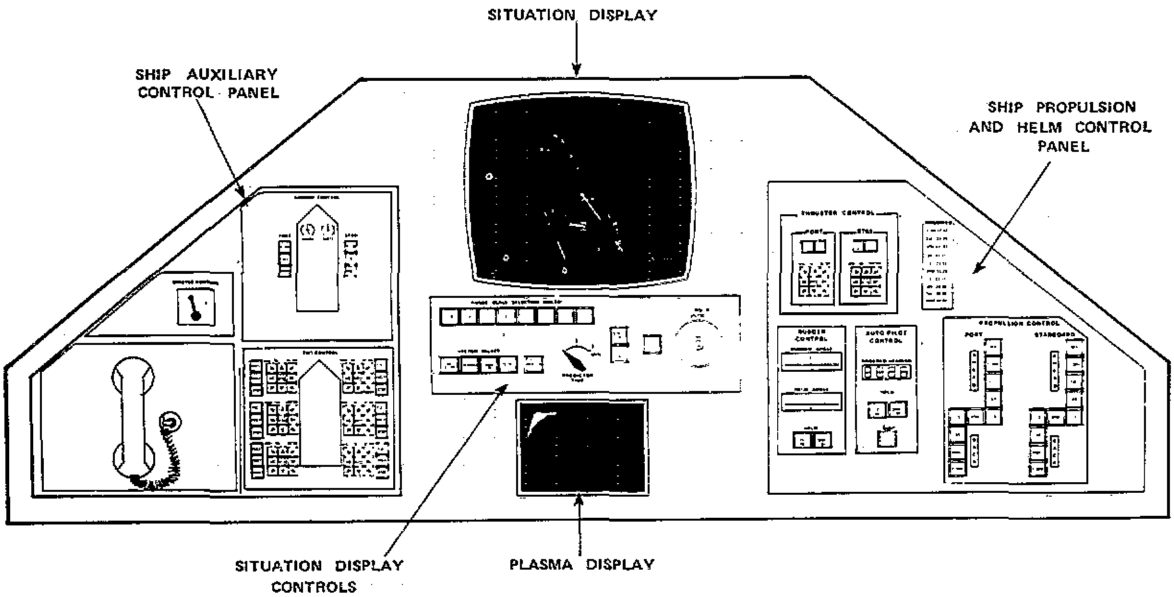

Figure 4. PARTT-SHIP Bridge Control Panel

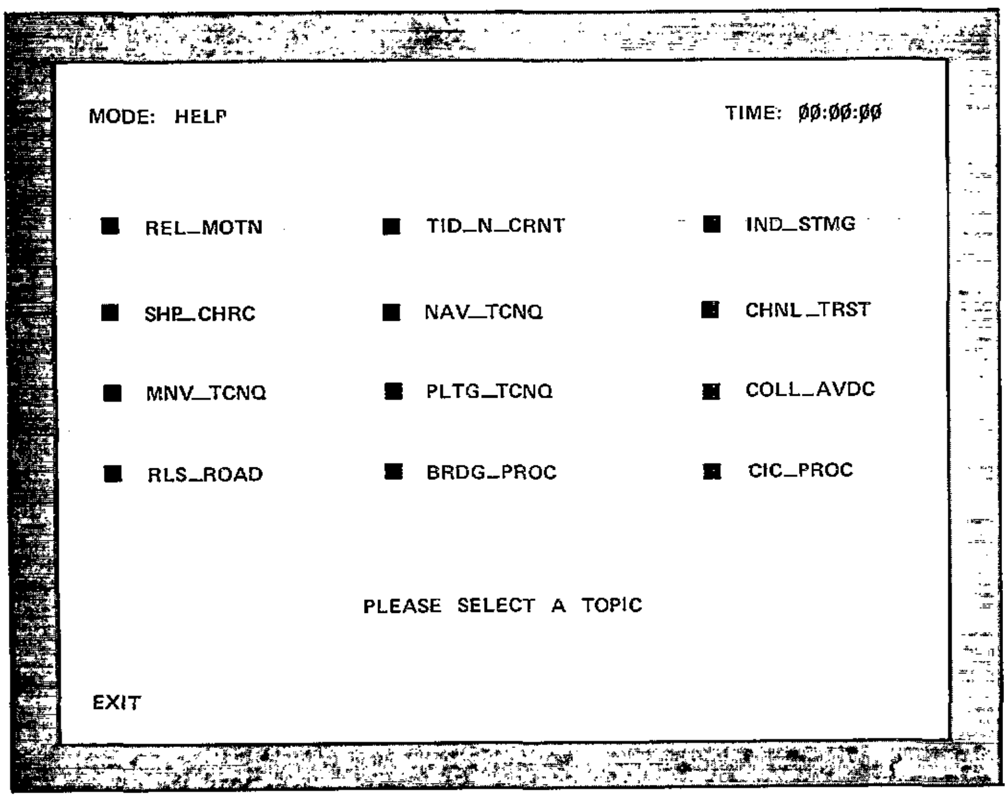

Figure 5. Plasma Console Showing an Example of a Tutorial "Help" Menu

the student in negotiating various restricted waters situations. A special set of vector functions are included as part of the PPI capability that will display past ownship track information, a predictor steering feature, and a *scenario freeze capability. The trainee may* choose to examine his historical performance or up to 3 minutes of the ships predicted future course. These functions are carried in fast time while the scenario is in run or is frozen. Traditional radar features (i.e., range and bearing) can also be displayed. Using a PPI representation, the student is less apt to attempt mastery of radar operations since operation of the PPI situation display is simplistic. Operating device controls demand little attention from the trainees to increase the probability that the student attends to the principles and concepts of shiphandling rather than the mechanical operation of the trainer.

Bridge Controls. The generic bridge design includes a number of stylized controls and indicators that were included to reduce the amount of familiarization time necessary within the trainer before training can begin (Figure 4). The controls are simple pushbuttons which simulate the function of real world bridge equipment. The stylized generic nature of the controls and indicators make the training device applicable across a wide variety of ship classes and ship types without sacrificing face validity. The goal of the design was to make the operation of the trainer straightforward and simplistic. This minimizes the necessary task demands for operating the device so that students can pay attention to the important information being displayed in the visual scene, situation display, and computer aided instructional display.

Gaming Area. The nature of computer generated imagery (CGI) systems is such that reprogramming of new gaming areas or switching from one gaming area to another can be done rapidly and inexpensively. Any number of major U.S. Navy ports or other ports of interest may be called upon for instructional purposes limited only by computer storage capacity and data base availability. Special features of each gaming area are accurately programmable since the environmental equations that model each data base are sophisticated. The effects of bank, cushion, shallow water, passing ship, current, wind, bottom composition, and a number of other environmental parameters are designed into the hydrodynamic equations that control the portrayed motion of ownship through the gaming area.

CAI Functions. A computer aided instructional capability has been designed for use before, during, and after exercise run. No shiphandling trainer presently uses a CAI feature, so its effectiveness will be closely *monitored in this project. These functions are* used to: explain the operation of the trainer, exercise objectives, and performance feedback information to the student. Additionally, CAI functions have the capability of interrupting a training scenario to question the trainee concerning various exercise scenario features with which the student should be familiar or should be anticipating during the exercise run. This feature cues the trainee so that he may direct his attention to important features within the exercise. It is also a means by which the instructor can judge how well the trainee is absorbing the instructional materials.

Before exercise run, a PARTT-SHIP "help" feature can be called upon for a brief tutorial of principles and concepts related to the scenario. The trainee need only touch the appropriate area on the plasma "help" display for a number of various menus to appear within which the student can select (Figure 5). Several levels of branching have been designed so that the student can access the level of instruction required for his particular entry level skills and knowledge. The tutorial structure is flexible yet easy to follow.

TRAINING EFFECTIVENESS EVALUATION

Design of the PARTT-SHIP model was a product of front-end analysis that included user inputs and expert analyses in the areas of training, operation, and engineering. Many design steps were taken to maximize potential training benefits to Navy shiphandlers. However, as in any development the validity of design must be examined through actual use. To avoid the incorporation of unneeded model features into the final engineering design, a series of model evaluations have been conducted.* Goals of the evaluations are to experimentally test the training effectiveness of the PARTT-SHIP design and to collect expert shiphandler evaluations of training potential for the existing model. Information gained from evaluations will be used to improve the final engineering design specification.

Two questions have been posed concerning the PARTT-SHIP model:

1. Can basic and intermediate level shiphandlers receive comparable training with the part-task trainer as with a full-scale shiphandling simulator?

2. *What features of PARTT-SHIP are neces*sary for good training, i.e., CGI, PPI, and CAI?

A training effectiveness evaluation (TEE) has been conducted to answer these questions and is described below.

Comparative Evaluations

Two experiments were planned to investigate the measurable training gains of the model. Each was designed as a before and after study to compare entry level shiphandling skills of junior Navy officers to skill levels demonstrated after training. Figure 6 is a diagrammatic representation of planned treatments and control groupings. The simplified block dia*grams and drawings below each capability repre*sent the configurations that will be compared. An example of one treatment is the "PARTT-SHIP

*Note: At the time of this writing, the evaluations were just beginning. Preliminary results of the study will be distributed. In addition, final results may be obtained by writing to the authors.

EXPERIMENTAL DESIGN

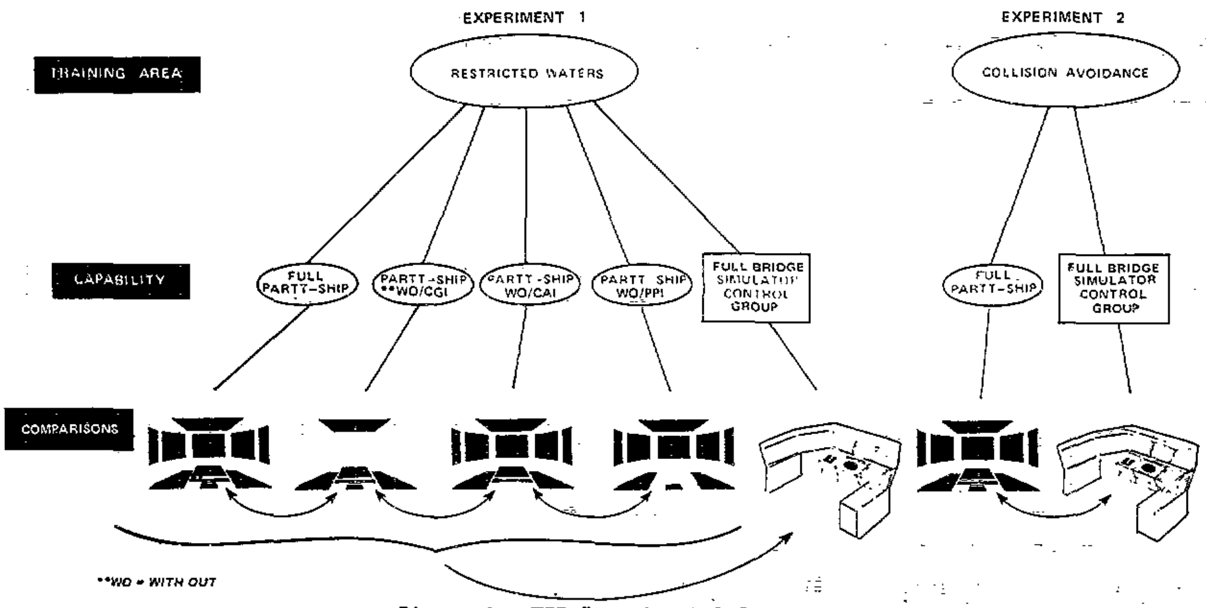

Figure 6. TEE Experimental Design

without (wo) CGI" (PARTT-SHIP without computer generated imagery) shown for Experiment 1. It can be seen that the CGI display screens are not included in that drawing.

Experiment 1 investigated the training effectiveness of the PARTT-SHIP model for restricted waters shiphandling. Subjects in this experiment were junior Surface Warfare Officer students from Surface Warfare Officer School (Basic).

The principal comparison was between training conducted on a full-mission bridge simulator and that conducted on the PARTT-SHIP model. Entry skill levels of students trained on either device were balanced along with scenario difficulty, scenario length, training objectives, instructors, and total time of training. This allows a direct comparison of final posttraining skills and training gains between training devices. Comparisons were also made between pretest and posttest performances within control and treatment groups to examine the total training gain.

Three other comparisons were planned to test the effectiveness of reduced PARTT-SHIP configurations. Reduced designs were accomplished by removing the CGI, CAI, and PPI subsystems one at a time and to test their individual effects. A separate group of trainees was instructed with each reduced version of the trainer. Each treatment (PARTT-SHIP) group was compared to one another and to a control group trained on a full-mission simulator.

Experiment 2 was a separate but similar experiment run with other groups of trainees within the area of collision avoidance but without the reduced trainer comparisons.

Qualitative Evaluation

Each experimental subject and all Navy personnel taking part in demonstrations of the model have filled out a device rating questionnaire. It was designed to record and quantify opinions of the model's training potential.

Research Hypotheses**

Expected findings from experimental efforts can be summarized in several specific hypotheses.

Hypothesis 1. Principal comparisons between treatment and control groups will show no difference. This would mean that the PARTT-SHIP model approaches or equals full scope bridge simulation training capabilities within the areas tested. This outcome was expected because of the similarity of functional capabilities in each device. Primary physical differences exist for the size of the bridge area and the fidelity of the bridge controls and control panels. Visual scenes are essentially the same. Training displays were the primary functonal difference.

Hypothesis 2. When comparing "reduced" versions of the PARTT-SHIP model to one another and to training on a full-mission simulator, removal of any one subsystem (i.e., CGI, CAI, or PPI displays) was expected to affect the speed of learning and therefore the total training effect. No a priori rankings of the training effectiveness of any one subsystem was predicted.

**Whether these hypotheses have been supported or refuted will be discussed in the additional pages distributed at the conference.

Hypothesis 3. Although performance gain was expected to be equal between control and treatment groups within either training area, subjects trained on the PARTT-SHIP model may have experienced a performance decrement during simulator posttest. This could have occurred since a degrading in performance between part- and full-task trainers was found by Williams, Goldberg, and D'Amico, 1980,[2] in a simulator study of Chief Mates shiphandling behaviors. Although training gains were equivalent for students training on a full-scope (full-task) simulator and a reduced bridge (similar to the PARTT-SHIP model), Chief Mates having trained on the reduced bridge experienced significant deficiencies in performance when transitioning to the higher fidelity full scope simulator for more training and testing. Although those subjects differed somewhat from the Navy population (i.e., junior Navy officers), it is reasonable to assume that such a deficit may occur in the PARTT-SHIP experiments during posttest.

Hypothesis 1 is not contradictory to Hypothesis 3 although the former predicted no difference between treatment and control groups while the latter predicted a possible difference. Hypothesis 1 was concerned with training effectiveness with respect to device types as measured by pretest/posttest comparisons. Hypothesis 3 predicted that subjects from treatment conditions, who were trained on the PARTT-SHIP device, may have experienced performance decrements on a full bridge simulator posttest following training. Hypothesis 1 was, therefore, a comparison of training gain within devices as measured on each device while Hypothesis 3 was concerned with measures of training effectiveness as measured by the simulator alone. These predictions were not mutually exclusive.

CONCLUSIONS

High accident rates over the last few years prompted the Chief of Naval Operations in 1979 to make the area of shiphandling training a high priority objective for improvement. The shiphandling training program under development at NAVTRAEQUIPCEN will go a long way towards meeting that objective. Special emphasis is being given to the numerous research questions which must be answered concerning the part-task device preprototype, especially since it is the first of its kind. Will it be training effective? Which elements of the device are most important? What will be the opinion of experienced shiphandlers about the efficacy of the device? The results from the current study will hopefully provide the answers necessary to make the part-task approach an effective and efficient element of the total shiphandling training system.

REFERENCES

1. Hanley, M. and Bertsche, W. "Naval Shiphandling Study." Report No. EA-82-U-005, Naval Training Equipment Center, Orlando, Florida, 1982.

2. Williams, K., Goldberg, J., and D'Amico, A. Transfer of training from low to high fidelity simulators. National Maritime Research Center, Kings Point New York, 1980.

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